Atomic-Scale Structural Studies of Te/Ge(001)

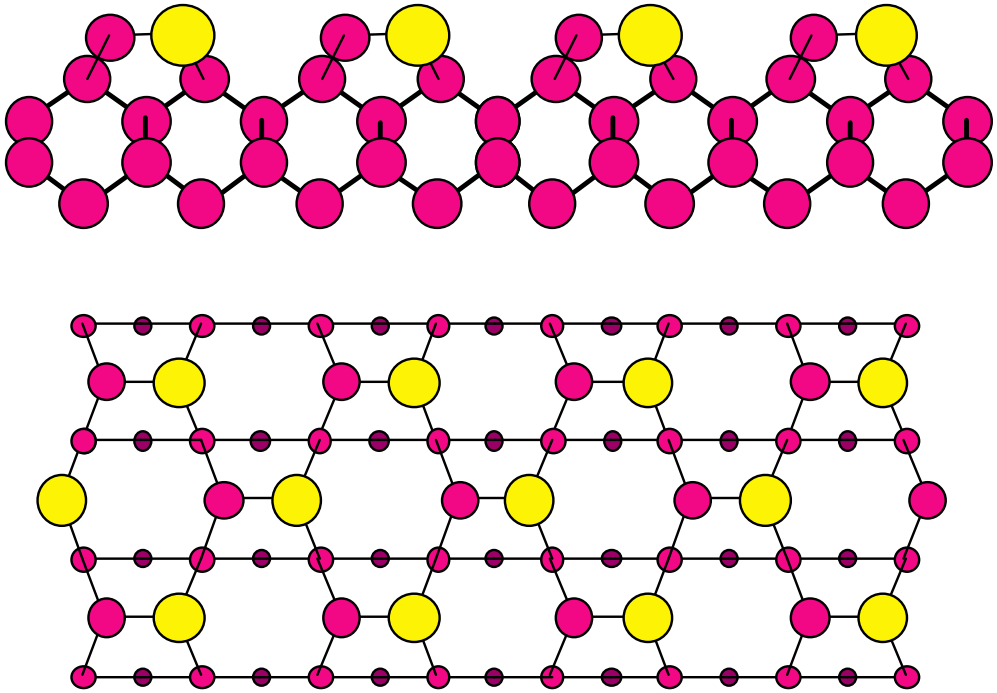

Fig. 1. Side and top view of model structure for the 0.5 ML c(2x2) Te/Ge(001) Surface featuring the formation of Te-Ge hetero-dimers.

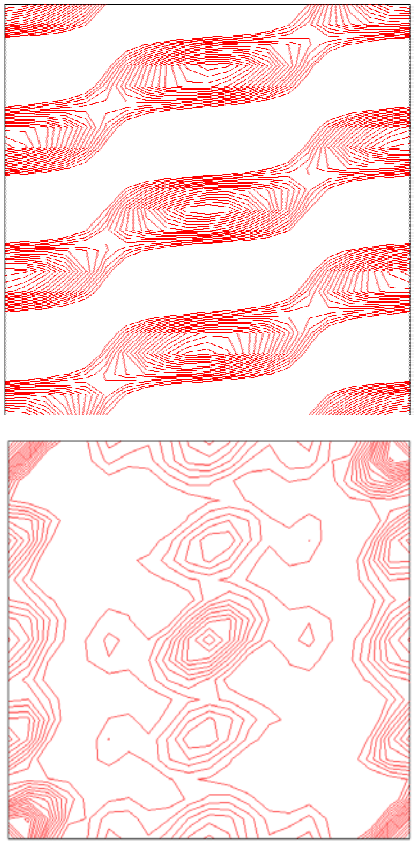

Fig.2. Top: Patterson Map for Experimental Data; Bottom: Patterson Map for Model Structure in Fig. 1

Materials Science/Atomic-Scale Structural Studies of Te/Ge(001); M. Bedzyk et al./Northwestern U; DMR-9973436. The chemical and electronic passivation of semiconductor surfaces is a crucial part of successful device processing. By passivating a reactive semiconductor surface, the probability of having surface defect states or fixed interface charges is greatly reduced, which in turn provides improved device reliability and performance. A passivated surface can also promote unique film growth phenomena, such as the case of surfactant-mediated epitaxy (SME), which depends on the presence of a passivating species during film growth. The reduced surface energy of the passivated surface can have a profound effect on subsequent film growth, which our group has investigated in the case of SME of Ge on Si(001) using Bi and more recently Te as surfactants. [Rodrigues *et al*, J. Appl. Phys. **88** 2391 (2000)]. In order to fully understand how Te behaves as a surfactant and passivating species, it becomes necessary to understand the atomic-scale structure of Te on semiconductor surfaces. Our group has previously performed x-ray standing wave (XSW) experiments and proposed a model (Fig. 1) for a 0.5 monolayer coverage of Te on Ge(001) that helps to explain why Te is an effective surfactant at low coverages [Lyman, *et al*, PRB **60** 8704 (1999)]. The measurements predict the quite unique formation of a Te-Ge hetero-dimer. The XSW measurement precisely determined the lattice position of the Te atom, but could not deduce the Ge surface atom positions. In order to strengthen our model, we have used surface x-ray diffraction to characterize this 0.5 ML c(2x2) Te/Ge(001) surface phase. Initial Fourier analysis of the structure factor collected is shown in the contour plot of the Patterson function, which is similar to a similar map produced from our model structure. Further Fourier analysis analysis of out-of-plane rod-scans are in progress and will provide a more complete understanding of this structure. Furthermore, we are now able to directly image the Te/Ge(001) structure using our in-house UHV MBE/STM system. STM images will provide local, direct-space information about defect structures and domain size, which will be a unique and powerful addition to our ensemble-averaged, reciprocal-space diffraction results.

NSF Nuggets:

Diversity in the science and engineering of semiconductor buried atomic layers.
The surface/x-ray research group of Prof. Michael Bedzyk at Northwestern University (DMR-9973436) works together at squeezing a confined planar-layer of germanium atoms into a matrix of silicon atoms. In addition to learning the tricks of how to grow this atomic sandwich and to characterize it with atomic-scale x-ray precision, this group learns how people from various cultural backgrounds can work together and support each other's goals. Supported over the three years of this NSF grant are: **Postdoctoral fellows:** Dr. Alexander Kazimirov (Ph.D. from the Russian Institute of Crystallography and now a staff scientist at the Cornell High Energy Synchrotron Source**),** Dr. Donald Walko (Ph.D. from UIUC and now a staff scientist at the Advanced Photon Source), and Dr. Kai Zhang (originally from China with a Ph.D. from University of Hamburg, Germany); **Graduate students**: William Rodrigues (special fellowship, received Ph.D. in 2000, originally from India and now a Research Engineer at ETEC/ Applied Materials, Portland, OR), Anthony Escuadro, Brad Tinkham (special fellowship, received Ph.D. in 2002), John Okasinski (special fellowship). **Undergraduate students**: Samerkhae Jongthammanurak and Worawarit Kobsiriphat (both had fellowships at NU from Thailand and did there senior research projects on the Si/Ge/Si project, Samerkhae is now a MIT Ph.D. graduate student), Socrates Vela (inner-city UIC student participated in Ge/Si/Ge project via the MRSEC/MRI program, Samir Patel (USC student participated via the MRSEC/REU program).

Michael Bedzyk / Northwestern DMR-9973436
For the past two summers a Chicago high school student, Valerie Casey, has worked on projects in the X-ray Facility at Northwestern that is directed by the Prof. Michael Bedzyk. One of her x-ray research projects was entered into a state competition and was awarded "The Illinois Junior Academy of Science, Top in Category for Materials Science". She has been accepted by Northwestern University and will begin her studies this Fall as a chemistry major.